NIF

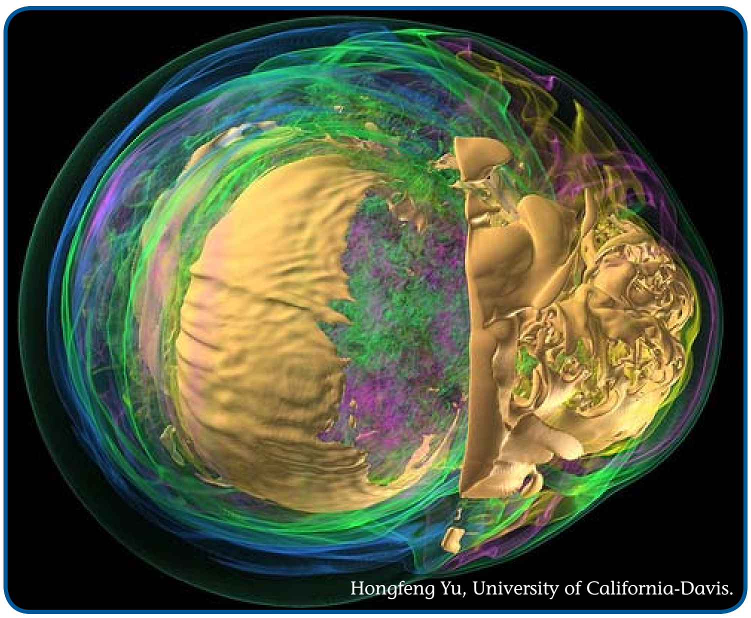
National Ignition Facility

A New Era of Experimental Science

Laboratory experiments at the National Ignition Facility will enable researchers for the first time to study the effects on matter of the extreme temperatures, pressures and densities that exist naturally only in the stars and deep inside the planets. Results from this relatively new field of research, known as high energy density (HED) science, will mark the dawn of a new era of experimental science. HED research at NIF promises to revolutionize our understanding of astrophysics and space physics, hydrodynamics, nuclear astrophysics, material properties, plasma physics, nonlinear optical physics, radiation sources and radiative properties and other areas of science.

Supernova 1987A

Experiments on NIF will reveal the nature and behavior of many astrophysical phenomena such as Supernova 1987A.



Hongfeng Yu, University of California-Davis.

Supernova

This astrophysics simulation from Argonne National Laboratory seeks to discover the mechanism behind core-collapse supernovas, or the violent death of short-lived, massive stars. The image shows entropy values in the core of the supernova, different colors and transparencies assigned to different values of entropy.

NIF will generate temperatures of more than 100 million kelvins (180 million degrees Fahrenheit); densities of about 1,000 grams per cubic centimeter; pressures more than 100 billion times greater than the Earth's atmosphere; and neutron densities of about 100 septillion (10^{26}) per cubic centimeter. Only three places in the space and time of our universe have ever produced anything close to these conditions: the Big Bang, when the universe was born in a primordial fireball; the interiors of stars and planets; and thermonuclear weapons. Nothing within orders of magnitude of these extraordinary conditions has been available for laboratory experiments until now. Because these conditions are so extreme, the connection between NIF and astrophysics is already causing excitement among scientists interested in using NIF to try to understand the objects in the cosmos, even to the beginning of the universe.

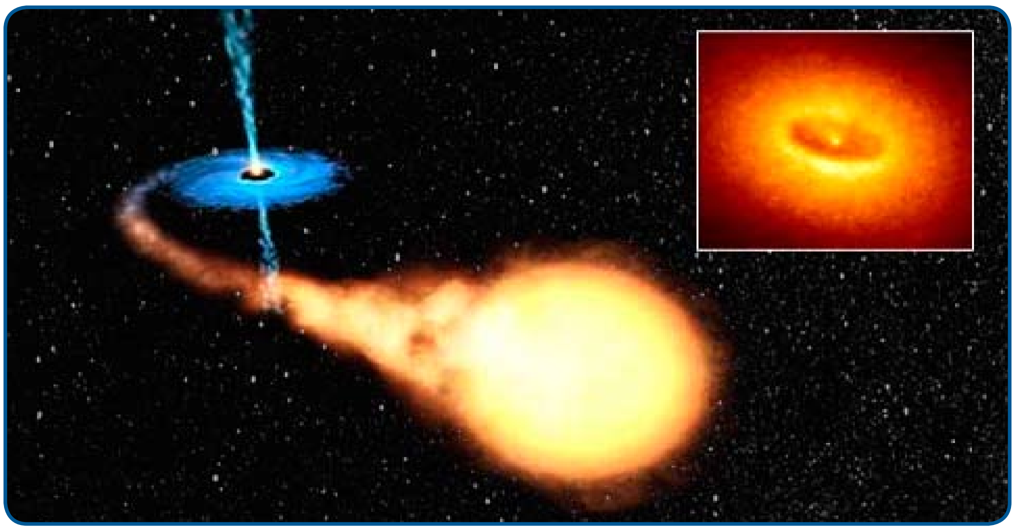
The temperature of burning hydrogen in the cores of stars for most of their lives is 10 to 30 million kelvins, or 18 to 54 million degrees Fahrenheit – much lower than the temperature expected to be achieved in the NIF target chamber. This phase of stellar evolution occurs at a density of some 100 grams per cubic centimeter, also well below what NIF will achieve. NIF's high pressures will permit planetary astrophysicists to study conditions at the cores of massive planets such as Jupiter and to understand why they are planets and not stars. The extreme neutron density at NIF is considerably larger than that in a core-collapse-type supernova – an exploding star – or when two neutron stars collide.

The conditions that NIF will produce will also permit research into:

- Materials at unprecedented pressures, and the possible phase changes that are certain to be discovered under these conditions.
- Plasmas, the material that makes up the stars and constitutes almost all of the known matter in the universe. These turbulent collections of electrons and ions that can carry electrical currents and generate magnetic fields are of interest not only for the production of energy from laser fusion, but also to astrophysics (much of our understanding of extreme objects, such as black holes, arises from studies of the X-rays emitted from the plasmas that are produced around them) and to nuclear physics (the extreme neutron density in NIF will permit never before possible studies of nuclear reactions on short-lived nuclear excited states).
- Instabilities produced by laser fusion. These phenomena are the same instabilities that are produced in some stellar conditions, such as supernovas, and so will provide a unique opportunity for astrophysicists to understand what makes stars, even exploding stars, operate the way they do.

A Massive Black Hole

An artist's concept of a black hole in a binary system shows a star (at right) feeding an accretion disk surrounding the black hole. The insert shows an image recorded by the Hubble Space Telescope of a massive black hole at the center of the galaxy NGC4261.



Laser-Plasma Interactions

Results of a laser-plasma interaction experiment compare favorably with a computer simulation of the same interaction. The target is compared in size with a pencil eraser.